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United States Department of Agriculture
Agricultural Research Service

Report of ANNUAL CORN AND WHEAT UTILIZATION CONFERENCE

Northern Utilization Research and Development Division
and
Corn Industries Research Foundation
Technical Committee

Peoria, Illinois

June 6, 1961

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FOREWORD

The Annual Corn and Wheat Utilization Conference was held on June 6, 1961, at the Northern Regional Research Laboratory. In attendance were members of the Corn Industries Research Foundation Technical Committee and staff members from the various laboratories of the Northern Utilization Research and Development Division. Opportunity was given to hear reports of research in progress at the Northern Division; to exchange ideas; and to suggest areas where research is needed.

SUMMARY

Dr. Senti reviewed briefly research on composition of minor constituents of corn, high-amylose corn; and starch reactions of glucose, amino starches, dialdehyde starch applications, graft polymers of starch; fermentation projects on insecticides, microbial polymers and β-carotene; the P. L. 480 research program encompassing 12 projects in 6 countries; and new major equipment acquired.

Studies on fractionation of high-amylose corn starch with the objective of preparing aqueous solutions of relatively pure amylose by leaching prefrozen starches were continued. Improvements in purity and yield of amylose obtained together with development of procedures of more general applicability were described.

Literature reports that high-amylose corn amylopectin was comparable in structure to that from dent corn were not substantiated. More intensive structural studies following differential sedimentation of the amylopectins with the ultra-centrifuge showed that the former differed from the latter in having longer external branches.

Zein was resolved into 5 major and 7 minor components by agar and starch gel electrophoresis. Zein, chemically modified to break disulfide bonds, gave an electrophoretic pattern similar to that from a commercial zein prepared by the normal SO_2 steeping process, indicating that disulfide bonds are broken in the steeping process and acidic groups are added.

Evidence was presented indicating that the polarimetric determination of starch in certain high-amylose corn starch samples yields low values as a result of difficulties in dispersion of the starch.

Diglucosylamine was prepared from glucose and the Amadori compounds, 1-amino-1-deoxy-D-fructose and imino-bis-1-deoxy-D-fructose were prepared from it as the acetates. These were found to be strong chelating agents for strontium, copper, and iron in the pH range 7-8.5 and crude mixtures of the two excelled saccharate in softening hard water at pH 9.

Effects of pH and concentration on cross-linking of casein by dialdehyde starch (DAS) in aqueous borax were investigated and found to give insoluble products varying in composition. Applied to paper as a pigment coating excellent wet-rub resistance was obtained with a paper coated at 50 percent solids containing 0.25 parts DAS and 12 parts casein to 100 parts clay.

A significant practical advance in the use of DAS as a wet-strength additive for paper has been made by studies involving reuse of white water. Good wet-strength development in papers by the use of cationic starch with DAS as reported last year appeared to be practicable but it was desired to improve retention of the amounts applied to make the operation more

efficient. Studies on recycling of white water, as usually practiced, however, have shown retention of DAS up to 98 percent and essentially quantitative retention of the cationic starch with consequent practical advantages.

Corn oil is composed principally of triglyceride esters of palmitic, stearic, oleic, and linoleic acids. The quantitative separation of the complicated mixtures possible and determination of the patterns of esterification have always presented problems. Fractionation of corn oil in a large counter-current distribution apparatus and determination of the fatty acid composition by gas chromatography has shown the fatty acid esters to be placed in a random pattern rather than in an even or a partial random distribution.

The formation of starch granules, as proposed by three different theories, intussusception, apposition, and coacervation, was discussed. The theory is proposed that apposition plus coacervation best explains the structures found in starch granules.

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service

Program

ANNUAL CORN AND WHEAT UTILIZATION CONFERENCE

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Peoria, Illinois
June 6, 1961

Morning Session

9:30 a.m.	Introduction..	F. R. Senti
10:00 a.m.	Fractionation of High-Amylose Starch............	E. M. Montgomery
10:30 a.m.	Basic Studies on Zein...........................	J. E. Turner
11:00 a.m.	Intermission....................................	
11:15 a.m.	Gross Composition of High-Amylose Corn..........	R. J. Dimler
11:45 a.m.	Preparation and Properties of Diglucosyl-amine and Related Compounds...................	J. E. Hodge
12:15 p.m.	Group Photograph	
12:30 p.m.	Luncheon	

Afternoon Session

2:00 p.m.	Dialdehyde Starch-Casein Paper Coatings	C. L. Mehltretter
2:30 p.m.	Dialdehyde Starch for Wet Strength Paper........	G. E. Hamerstrand
3:00 p.m.	Glyceride Structure of Corn Oil.................	C. R. Scholfield
3:30 p.m.	Possible Mechanisms of Starch Formation.........	S. R. Erlander
4:00 p.m.	Open Discussion	

INTRODUCTION

F. R. Senti

After welcoming visitors and introducing attendees, Dr. Senti discussed a few points of general interest including an increase in the 1962 appropriation for cereals research; the Division staff, augmented by 32 summer employees, has reached 432; and honors have recently been conferred on 3 employees, Drs. H. M. Teeter, J. C. Cowan, and Odette L. Shotwell, by the Department of Agriculture, American Oil Chemists' Society, and Montana State College, respectively.

Research on cereals at NU is in the following areas:

1. Minor constituents of corn

2. High-amylose corn analyses of around 16,000 samples per year for the hydrid breeding program

3. High-amylose corn starch fractionation and characterization

4. Extruded amylose films

5. Reactions of glucose

6. Fermentation studies on cereal-based media including biological insecticides, toxicants and repellents, microbial polysaccharides, and β-carotene. (Yields of β-carotene have reached 1.7 percent on a dry basis and commercial production by this process seems assured.)

7. Dialdehyde starch applications in paper

8. Graft polymers of starch

Included in contract research are graft polymers of starch at a research institute, a 3-year study on synthesis of amino starches with Dr. M. L. Wolfrom, Ohio State University, and the P.L. 480 research program involving 12 research projects at 11 research institutes in 6 countries.

New equipment of note acquired includes an electron microscope to be used in studies of wheat and corn kernel structure, starch granules, and cell walls and a nuclear magnetic resonance analyzer.

FRACTIONATION OF HIGH-AMYLOSE CORN STARCH

Edna M. Montgomery

Studies on the fractionation of high-amylose corn starch were directed toward development of an extraction procedure that would yield aqueous solutions of amylose having relatively high purity. High-amylose corn starch differs markedly from ordinary dent corn starch in showing greatly reduced or even negligible swelling and pasting in boiling water, together with increased temperature of gelatinization covering a range from 80° to 140° C. Amylose was extracted in only low yields from high-amylose corn starch in hot water.

Marked changes in properties occur when the starch is hydrated in an aqueous slurry at 25°, frozen to a hard cake and thawed. The pretreated starch gelatinized at 92° to 94° with swelling of the granule. Amylose was extracted from the prefrozen starch in good yield in boiling buffered water, leaving the residual starch in aggregated insoluble form, readily separated by sedimentation at 2000 X g. Leaching of prefrozen starches in 2 to 10 percent suspensions yielded in the first extract 70 to 75 percent of the amylose present with a purity of 85 to 92 percent, as shown by iodine binding. An additional 20 to 25 percent of the amylose was obtained by two or more extractions. The total amylose in the high-amylose starches was 80 to 82 percent of the apparent amylose shown by iodine affinity. Concentrations of amylose up to 4 percent in water were obtained. Amylose solutions retrograded slowly at 25°. No visible increase in turbidity occurred during 3 to 4 hours. Addition of ethanol or sodium salicylate with ethanol to starch slurry before freezing increased the purity to 90 percent or higher. Amylose was extracted in 80 percent yield at 110° C. in presence of ethanol from corn prefrozen in aqueous sodium salicylate. The fractionation procedure was applied to a series of two hydrid and eight inbred corn starches having apparent amylose content of 50 to 68 percent by iodine affinity.

The amylopectin component of the high-amylose starches was studied more intensively and shown to differ from ordinary dent corn amylopectin as indicated previously. The presence of longer external branches in amylopectin from high-amylose starch was evident from the higher iodine binding, higher β-amylase convertibility, and ease of retrogradation. A direct test refuted the claim by C. T. Greenwood of Edinburgh that the high iodine binding resulted from contamination with low molecular weight amylose separable by differential sedimentation in the ultracentrifuge.

Comments

Discussions during and following the presentation brought out some other points of interest. The fractionation technique was also applied with success to undried or slurry starch prepared by wet milling (SO_2 steep). Variation of the rates of freezing (-10°, -29° and -78° C.) had little effect on the fractionation. One effect of the freezing technique on high-amylose starch was to increase the solubility of the starch (air dried at 25°) in dimethyl sulfoxide (DMSO) from 5 percent to 20 percent. Dent corn is very soluble in DMSO.

BASIC STUDIES ON ZEIN

J. E. Turner

Zein, the prolamine in corn seeds, is soluble in aqueous solution only at high pH or in the presence of 7-8 M urea. For electrophoresis of proteins, a high pH limits the resolution that can be expected, while high concentrations of urea produce anomalous patterns in moving boundary electrophoresis. Since urea does not interfere with gel electrophoresis, this method was adopted for studying zein. Zein was resolved into five major and seven minor components by agar and starch gel electrophoresis. The resolution was attained in 24 hours with a field strength of 20 volts/cm. in an 8 M urea-aluminum lactate buffer at pH 3.5. In this system a large fraction of whole zein remained at the origin during electrophoresis. When disulfide bonds of zein were cleaved with sodium sulfite or performic acid, this immobile fraction was no longer observed. The electrophoretic pattern of the modified zein was similar to that of a commercial zein prepared from seeds that had been previously steeped in aqueous sulfur dioxide solution. The commercial steeping process apparently reduced disulfide bonds and added acidic groups to the zein molecule, thereby changing the electrophoretic properties.

Comments

Under conditions used there was little deamidation or loss of amide nitrogen. The bands found appear to be monomers of zein, but, as yet, there has been insufficient material to cut out bands and characterize further. Under conditions used all disulfide bonds appear broken and there was no sulfhydryl exchange.

GROSS COMPOSITION OF HIGH-AMYLOSE CORN

R. J. Dimler

The applicability of the polarimetric starch determination to high-amylose corn has been opened to question by our recent studies. Alternatively high-amylose corns thus far developed may tend to run low in starch content. Although a choice cannot yet be made between the two possibilities, a review of the present status of work on the problem is desirable because of the continuing interest in the breeding and commercialization of high-amylose corn.

Ordinary dent corn contains around 72 percent starch on a moisture-free basis. In contrast, four high-amylose corn samples (49 percent to 67 percent amylose equivalent) had from 58 to 63 percent starch by polarimetric analysis. In order to determine whether starch was lower as a result of increases in other constituents, additional analytical data were obtained on three corns, two of which were hand-dissected into endosperm, germ, and pericarp for further analysis.

For one high-amylose corn, the lowering of starch to 61 percent could be accounted for reasonably well by increases in protein, fat, pentosans, and solubles. The other two high-amylose corns, however, still showed a discrepancy of some 7 percent when the analytical values were added up.

Hand-separated endosperm of two high-amylose corns contained 70 and 74 percent starch, compared with an average of 86 percent for a number of dent corn endosperm samples. The sum of starch, protein, and fat accounted for only 84-85 percent of the endosperm for the two high-amylose corns, compared with 96 percent for dent corn endosperm. Solubles, fiber, and pentosans amounted to only 5 percent in one high-amylose endosperm, thus providing no basis for explanation of the difference.

Evidence that the polarimetric procedure was not measuring all the starch was provided by data on amylose determinations on the endosperm as compared with those on the isolated starch. For the amylose determination, the endosperm is defatted, water washed, and analyzed for moisture, protein, and amylose equivalent (spectrophotometrically at present). The amylose content of the endosperm starch is calculated on the basis of correction of the sample weight for moisture and protein, the rest being taken as starch. If the actual starch content were low, the calculated amylose content of the starch from the endosperm analysis should be correspondingly low when compared with direct determination of the amylose equivalent on the isolated starch. Instead, either there was good agreement between analysis on endosperm and on starch or the result was higher on the endosperm for the nine corns on which data were available.

The difficulty with which most high-amylose starches are gelatinized and dispersed leads to the suggestion that the low values for starch in the endosperm result from incomplete dispersion of the starch in the calcium chloride prior to polarimetric measurement. This is now being investigated.

Comments

The question was raised about a possible rapid method for measuring amylose content of starch or a good qualitative test for use in the field. Other methods of possible application such as sedimentation, precipitation, and optical rotation still require laboratory facilities.

PREPARATION AND PROPERTIES OF DIGLUCOSYLAMINE AND RELATED COMPOUNDS

J. E. Hodge

Muskat's method for preparing D-glucosylamine from D-glucose and anhydrous, liquid ammonia yields 13-18 percent di-D-glucosylamine along with D-glucosylamine and the glucose-ammonia addition compound. Varying Muskat's procedure, with and without ammonium salt catalysts, and at temperatures below the ammonia boiling point (-33° C.) up to 60° C. under pressure, gave appreciable yields of di-D-glucosylamine in every experiment. The yield of di-D-glucosylamine was markedly increased by stirring anhydrous D-glucose in liquid ammonia, 0.5 M with ammonium chloride, and with an excess of anhydrous calcium sulfate ("Drierite") to take up the water of condensation and to inhibit excessive browning in the subsequently heated mixture. Evaporation of the ammonia, addition of methanol, and refluxing of the ammoniacal methanol-Drierite mixture with continuous stirring finally produced a filtrate and evaporated residue that contained 60-64 percent (of theory) di-D-glucosylamine and 18-24 percent (of theory) mono-D-glucosylamine. Yields were determined by fractional crystallization of the respective octa- and penta-acetates after acetylation of the evaporated residue in pyridine-acetic anhydride at 25° C. A control experiment showed that mono- is not converted to di-D-glucosylamine under the acetylation conditions.

Di-D-glucosylamine is readily converted to imino-bis-1-deoxy-D-glucitol by catalytic hydrogenation and to the acetate salt of imino-bis-1-deoxy-D-fructose (the Amadori compound) by heating in glacial acetic acid. These two new compounds are much stronger chelating agents for strontium, copper, and iron in the pH range 7 to 8.5 than D-glucosylamine, N-acetyl-D-glucosylamine, di-D-glucosylamine, or N-acetyl-di-D-glucosylamine. Explanation is offered based on stronger basicity of the nitrogen atoms in the hydrogenated and Amadori compounds and on the existence of these derivatives in open-chain, rather than in relatively sterically fixed ring structures.

The Amadori compounds, 1-amino-1-deoxy-D-fructose and imino-bis-1-deoxy-D-fructose (on a weight basis as the acetate salts), and crude mixtures of the two were more effective in the softening of hard water at pH 9 than gluconate, glucoheptonate, or the glucosylamines; and crude mixtures of the two excelled saccharate, according to the standard soap titration method for determining water hardness.

Comments

No additional work is planned beyond publication of results. Amino compounds of glucose should be investigated as industrial sequestrants.

The question was later raised as to toxicity of ammonium derivatives of glucose having medicinal applications. Sugar amine reaction products can be toxic, and, while it is not believed that the diglucosyl amines are toxic, they have not been tested.

DIALDEHYDE STARCH-CASEIN PAPER COATINGS

C. L. Mehltretter

Effects of pH and concentration on crosslinking of casein by dialdehyde starch in aqueous borax dispersions were investigated. Varying the ratio of dialdehyde starch to casein gave insoluble products differing in composition. Maximum combining capacity of polymeric dialdehyde was found to be 25 g. per 100 g. of casein. Viscosity stability of dialdehyde starch-casein dispersions was achieved by appropriate combinations of reagents under slightly acidic conditions. Rapid reaction and gelation occurred at pH levels above 7.

The information obtained in the above basic study was applied to the pigment coating of paper. Excellent wet-rub resistance was obtained with paper coated at 50 percent solids containing 0.25 part dialdehyde starch and 12 parts of casein to 100 parts of clay. Better efficiency of insolubilization of casein by dialdehyde starch was observed when the coated paper was dried at 140° C. for 30 seconds.

Comments

The practical temperature for drying coated paper should not exceed 140-150° C. Viscosity cannot be reduced once it has gone up, but can be held if pH is kept low. Dialdehyde starch has the advantage over formaldehyde in being nontoxic and producing no fumes. An alkaline pH is normally used because of a faster cure, and can be attained by a light spraying, but some yellowing is a problem.

DIALDEHYDE STARCH FOR WET-STRENGTH PAPER

G. E. Hamerstrand

A significant practical advance since our report on this subject last year is the achievement of greatly increased efficiency of dialdehyde starch (DAS) retention in handsheet and Fourdrinier paper machine systems by employing recirculation of white water. Another finding has been the greatly improved dry- and wet-strength properties imparted to the less refined pulps. With retentions of 0.3 to 1.0 percent DAS (pulp dry basis), the average wet tensile strength for a variety of pulp types was 40 percent with a maximum of 60 percent of that for untreated, dry, control papers. Equally important were dry strength increases ranging from 40 to 240 percent.

Because DAS has little or no affinity for cellulose fibers its use as wet-end additive in paper is dependent upon the use of a retention aid--a material required to bring about rapid and significant adsorption of DAS on the cellulose fibers. Studies of various retention aids have shown cationic starches to be highly effective for this purpose.

However, even by use of a retention aid such as cationic starch maximum retention of DAS has been only 60 percent, with the remaining 40 percent lost in the white water. In order for the DAS to be more competitive with the commercial resins it was necessary that the efficiency of the system be improved. To this end re-use of white water has been investigated. Results of such studies conducted on both handsheet and machine-prepared paper have shown that up to 98 percent effective retention of DAS is possible, with near quantitative retention of cationic starch. In general, operating advantages as well as significantly improved physical properties of the paper are realized.

White water recycling, a common and necessary paper mill practice, has proved extremely beneficial in terms of efficiency and consequent economic advantages with DAS-cationic starch.

<u>Comments</u>

On continuous immersion one-half the wet strength contributed by DAS may be lost in 24 hours, offering no septic tank problems with disposable tissues. Loss of strength on storage of paper is nil at relative humidities below 80 percent; above 80 percent, loss in strength will appear, varying with humidity levels.

Recycling of white water is a common and necessary mill practice for water economy and control of losses. DAS does not react with the felt on the Fourdrinier as some other synthetics do, thus maintaining normal felt life.

GLYCERIDE STRUCTURE OF CORN OIL

C. R. Scholfield

Corn oil is made up principally of triglyceride esters of palmitic, stearic, oleic, and linoleic acids. Since there are four different fatty acids and three places for them to be esterified on the glycerol molecules, a large number of different triesters are possible. The quantitative separation of an individual triglyceride from such complicated mixtures is quite difficult and has only rarely been accomplished. Various patterns for the distribution of fatty acids among the triglyceride molecules have been suggested. These include the "even" pattern in which each fatty acid is distributed among the triglyceride molecules as widely as possible, and the "random" pattern in which the fatty acids are arranged according to chance. Doerschuk and Daubert, who fractionated corn oil by low temperature crystallization, suggested in 1948 that it had a partial random pattern.

At this laboratory countercurrent distribution has proved to be the best tool yet available for the fractionation of the more unsaturated fats and oils. Using a large automatic countercurrent distribution apparatus, linseed oil, soybean oil, and safflower oil have previously been shown to approximate a random distribution, while cocoa butter, a more saturated solid fat, does not. Now corn oil has also been shown by countercurrent distribution to approximate a random pattern. The weights of the countercurrent distribution fractions and their fatty acid composition as determined by gas chromatography agree with a random distribution rather than with an even or partial random distribution.

Comments

Trilinolein amounts to about 20 percent of corn oil. Earlier work on glyceride structure was inaccurate because of inadequate methods. Certain assumptions had to be made which turned out to be wrong.

POSSIBLE MECHANISMS OF STARCH FORMATION

Stig R. Erlander

Three previously proposed theories for the formation of starch granules are discussed: intussusception, apposition, and coacervation. It is proposed that starch is produced in a common medium (stroma) and that it separates as a gel (coacervate) initially on the grana in the plastid. Afterwards these grana and surrounding starch act as nuclei for a series of phase separations, which may occur as much as 3 or 4 days apart (apposition plus coacervation). The threads connecting the grana determine the structure of compound or semicompound granules. The heavy concentric rings, as observed under a light microscope, may result from these phase separations. Protein may be attached to these layers. The light concentric rings and spherite cross are probably due to twisting radial crystallites formed as the separated gel phase crystallizes. Absence of crystallinity in $\underline{su_1}$ genotype and immature starches is most likely due to high degrees of branching. The crystallite may be composed of amylopectin molecules that have their exterior chains intertwined with adjacent amylopectin molecules to form double helices. The interior part of the amylopectin may act as a "rigid block" or extender for the growing crystallite. Most of the amylose in the starch granule may fold back and forth on itself in a radial manner like linear synthetic polymer spherulites, to form "bundles" of amylose molecules.

Comments

In the structure of the starch granule there are both large and small "growth" rings. In some cases the time for formation of large rings is about 3 days. There is no direct evidence that the heavy rings are richer in protein, but they could possibly be composed of enzymes or other proteins which complex on the outer layer of the granule between the phase separations, i.e., during the possible 3-day period.

In wheat starch, small granules appear about 12-14 days after pollination from a new crop of plastids formed at that time, and they never have time to attain the size of the granules which were initiated at the time of pollination (fertilization).

GENERAL DISCUSSION

Mr. Goodwin commented favorably on the broader spectrum of studies presented. It is frequently of value to discuss things on which we have little information to bring out our need for such information.

In a discussion of the status of microbial polysaccharides Dr. Senti stated that three are now out for commercial evaluation. There have been some applications disclosed and others not disclosed. A variety of products can be produced, but cost of purification is a major factor. Some suggested uses, however, do not require high purity.

The possibility of presentations of fundamental research and work of the Pioneering Laboratory on these programs will vary with what is ready for publication. The Pioneering Laboratory is studying photosynthetic bacteria--cell wall structure and chemical syntheses in the cell. A show of hands indicated a desire to hear a report from this group next year.

Mr. Goodwin also commented on the excellence of slides presented, and indicated that a limited discussion, by our photographer, of methods used for preparation, would be welcomed.

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List of Attendance

CORN INDUSTRIES RESEARCH FOUNDATION TECHNICAL COMMITTEE

Corn Industries Research Foundation, Inc., Washington, D.C.
J. T. Goodwin, Jr., Technical Director

American Maize-Products Company, Roby, Indiana
J. W. Evans, Vice President - Research
E. L. Powell, Assistant Director of Research
B. M. Winner, Assistant Director of Research

Anheuser-Busch, St. Louis 18, Missouri
A. J. DeGrand, Manager, Production
V. R. Kurt, Chief Chemist
B. L. Scallet, Associate Director, Central Research Department
R. J. Sumner, Director, Central Research

Clinton Corn Processing Company, Clinton, Iowa
A. D. Campbell, Assistant Research Director
R. P. Jurgensen, Senior Vice President
G. T. Peckham, Jr., Research Director

Corn Products Company, Argo, Illinois
Harry Gehman, Director of Research
R. J. Smith, Section Leader
A. L. Wilson, Assistant Director of Research

Hercules Powder Company, Wilmington, Delaware
R. E. Chaddock, Director of Development

The Hubinger Company, Keokuk, Iowa
J. M. Seitz, Director of Research

Keever Starch Co., 324 Dering Road, Columbus, Ohio
R. L. High, Director of Research
Roy Hyldon, Assistant Research Director

National Starch and Chemical Corporation, Plainfield, New Jersey

C. G. Caldwell, Research Director
O. B. Wurzburg, Associate Director of Research

Penick and Ford, Ltd., Cedar Rapids, Iowa

W. C. Black, Research Chemist
Erling Hjermstad, Research Chemist

A. E. Staley Company, Decatur, Illinois

J. A. Bralley, Vice President - Research and Development

Union Starch and Refining Company, Granite City, Illinois

R. E. Pyle, Research Director
Y. S. Kim, Chemist

NORTHERN UTILIZATION RESEARCH AND DEVELOPMENT DIVISION

F. R. Senti, Director
W. C. Witham, Assistant Director
L. L. McKinney, Assistant Director
D. L. Miller, Assistant Director
H. M. Teeter, Assistant Director
J. E. Hubbard, Assistant to Director

W. K. Trotter, Agricultural Economist
K. R. Majors, Extension Grain Utilization Specialist

Cereal Products Laboratory

C. E. Rist, Chief
R. A. Buchanan
M. E. Carr
L. A. Gugliemelli
G. E. Hamerstrand
B. T. Hofreiter
D. J. Kay
A. M. Mark
M. L. Mednick
C. L. Mehltretter
F. H. Otey
J. C. Rankin
C. R. Russell
W. C. Schaefer
J. W. Sloan
F. B. Weakley
M. O. Weaver
C. A. Wilham

Cereal Properties Laboratory

R. J. Dimler, Chief
G. E. Babcock
J. A. Boundy
S. R. Erlander
B. E. Fisher
H. L. Griffin
J. E. Hodge
A. R. Jeanes
J. P. McGuire
E. M. Montgomery
B. F. Moy
E. C. Nelson
J. A. Rendleman
K. R. Sexson
N. W. Taylor
Robert Tobin
J. E. Turner
J. S. Wall
M. J. Wolf

Engineering and Development Laboratory

E. L. Griffin, Jr., Chief
R. A. Anderson
C. Vojnovich

Fermentation Laboratory

R. W. Jackson, Chief
R. F. Anderson

Industrial Crops Laboratory

I. A. Wolff, Chief

Oilseed Crops Laboratory

C. R. Scholfield

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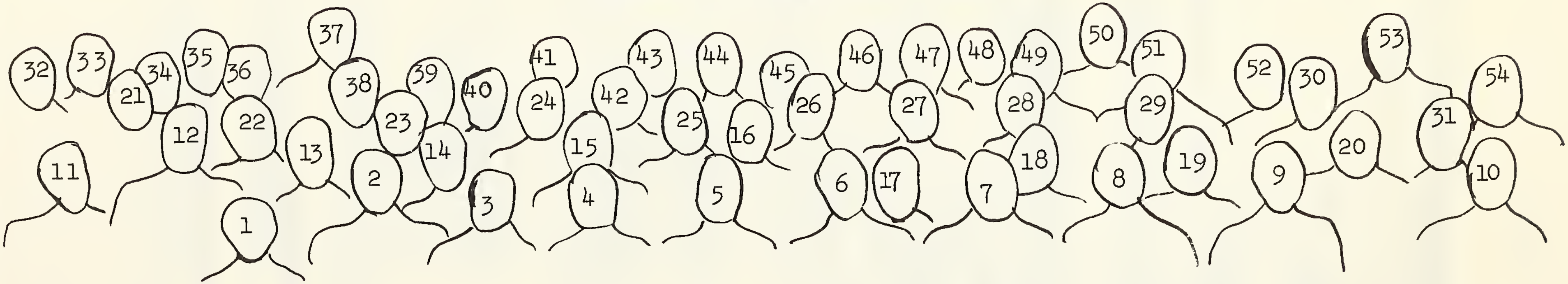

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3 Campbell, A.D.
4 Senti, F.R.
5 Goodwin, J.T.,Jr.
6 Wurzburg, O.B.
7 Jurgensen, R.P.
8 DeGrand, A.J.
9 Dimler, R.J.
10 Hyldon, Roy

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16 Trotter, W.K.
17 McGuire, J.P.
18 Babcock, G.E.
19 Peckham, G.T.,Jr.
20 Sumner, R.J.

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23 Evans, J.W.
24 Hjermstad, E.
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30 Griffin, H.L.
31 Kim, Y.S.

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